2013 Revised
Official Yield Estimate and
Long-Range Water Demand Forecast

Inputs and Assumptions for the Firm Yield Estimate

Firm yield of the water supply system is estimated using a simulation model developed by Seattle Public Utilities called the Conjunctive Use Evaluation (CUE) model. Additional details of the model and inputs are documented in the final report titled *Firm Yield of Seattle's Existing Water Supply Sources*, November 2011, prepared by Seattle Public Utilities (SPU). This estimate is unchanged from what was included in SPU's *2013 Water System Plan* (WSP).

Model Inputs and Assumptions

- ⇨ Firm yield is based on the **98% reliability standard**—one shortfall occurs in the 81 years of historic record.
- ⇨ **Historic weekly inflows** reconstructed for water year 1929 through 2009 are used.
- ⇨ **Total system demand** is shaped on a monthly demand pattern based on the average of actual deliveries from calendar year 2005 through 2009.
- ⇨ **Sources of supply are operated conjunctively as a single system.**
- ⇨ **Operational assumptions include:**
  - Cedar River System:
    Meet Cedar River Habitat Conservation Plan instream flow commitments below Landsburg, assuming flashboards in place on Overflow Dike.
    Fixed rule curve for Cedar Reservoir of 1550' for October-February and 1563' for May-August.
    Minimum levels for Chester Morse Lake: 1532'; Masonry Pool: 1510'
    Meet diversion limits specified by the 2006 Agreement with the Muckleshoot Indian Tribe.
  - South Fork Tolt System:
    Meet instream flows from 1988 Tolt Settlement Agreement (with treatment project).
    Fixed rule curve 1754' for October-January; 1765' for March-August.
    Minimum level for South Fork Tolt Reservoir: 1710'
    Treatment/Transmission capacity: 120 MGD
  - Seattle Well Fields:
    10 MGD withdrawn for 14 weeks as needed from July-December.
    5 MGD recharged for 14 weeks from January-March.

Results

Based on the above, **the system-wide firm yield is 172 million gallons per day**.

Inputs and Assumptions for the Water Demand Forecast Model

This revision to SPU's official water demand forecast is the same as that presented in the *2013 Water System Plan* with the exception that it reflects the 2nd amendment to and restatement of the declining block water supply agreement with Cascade Water Alliance signed in July 2013.

SPU is using the same basic water demand forecast model that was developed for the *2007 Water System Plan*. Following a literature review of demand forecast models used by other utilities, SPU settled on a "Variable Flow Factor" approach. As with simpler fixed flow factor models, current water demand flow factors are calculated by sector (single and multi- family residential, non-residential) for Seattle and each individual wholesale customer. However, like an econometric model, the Variable Flow Factor model reflects the impacts of variables such as price, income, and conservation on water flow factors for each sector over time. This approach takes advantage of past econometric analysis to provide estimates of how some of the variables (price and income) affect demand. SPU's Conservation Potential Assessment (CPA) Model and new Passive Savings model are then used to estimate the impacts of programmatic and passive conservation on the flow factors over time. The structure of the model is summarized in the flow chart on the next page while the model inputs and assumptions are outlined, below.

The structure of the water demand forecast model is represented in the flow chart on the following page. Intermediate steps and final results are shown as rectangles. Model inputs are shown as ovals with the gray shaded ovals indicating which inputs are subject to uncertainty and modeled using Monte Carlo simulations. The only real change in the flowchart since 2007 is the addition of household size as a factor affecting residential flow factors over time.

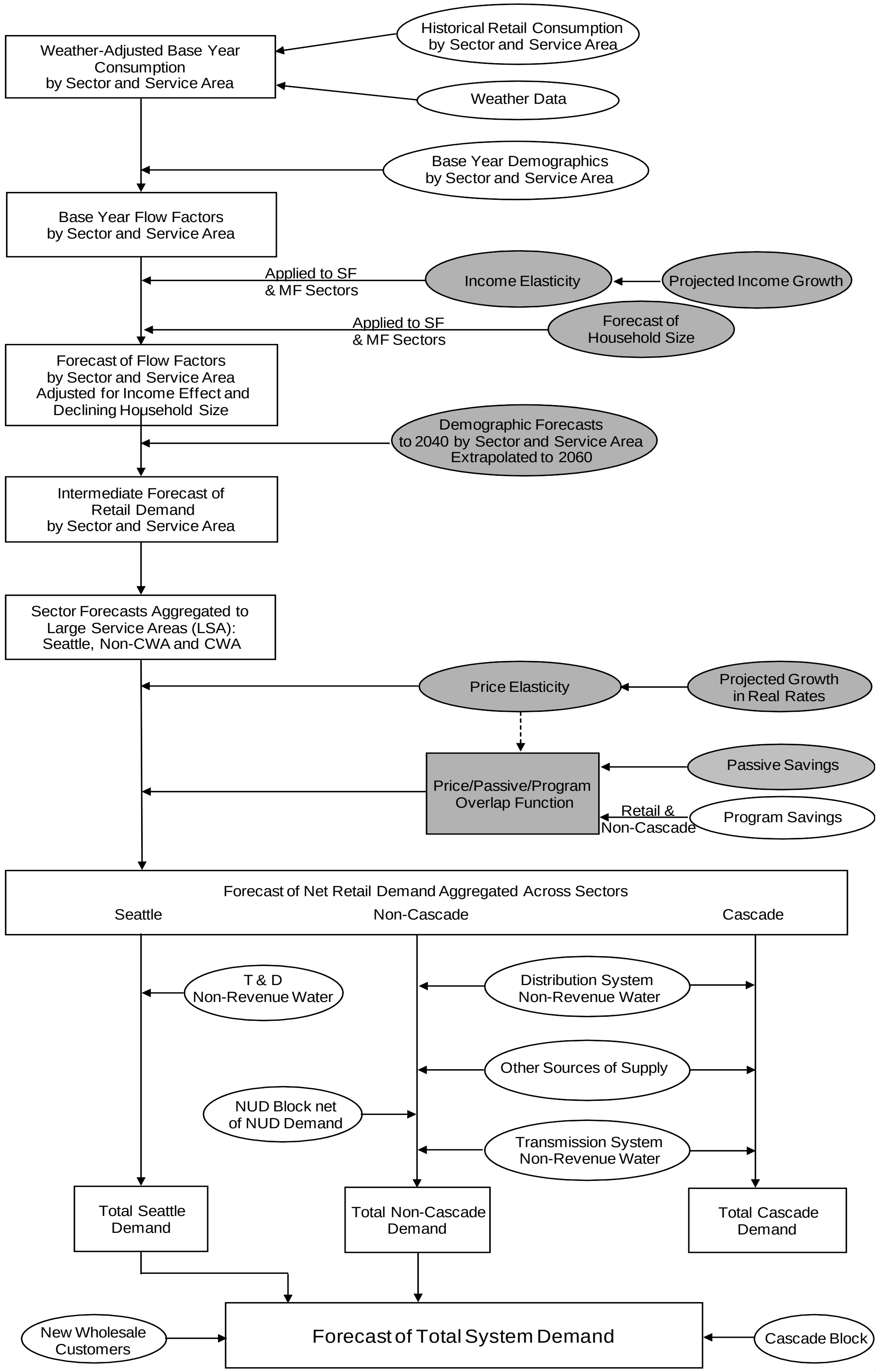
Model, Inputs and Assumptions

- **Weather adjusted base year consumption:**
  - By sector
    - single family residential
    - multifamily residential
    - manufacturing non-residential
    - non-manufacturing non-residential
  - By service area
    - Seattle-inside city limits
    - Seattle-outside city limits
    - Individual wholesale customers
  - Base Year
    - 2010
  - Weather
    - Sea-Tac Airport monthly average daily temperature and total precipitation

  Sources: SPU billing data, Annual Purveyor Surveys, NOAA

- **Demographics: Current and projected single- and multi-family households and employment:** The model uses Puget Sound Regional Council (PSRC) 2006 TAZ-level forecasts of population, households and employment to 2040 apportioned to Seattle and individual wholesale service areas. (These are the most recent forecasts available.) A straight line extrapolation of average annual growth between 2010 and 2040 is used to forecast beyond 2040. Household and population data from the 2010 Census and PSRC 2010 employment estimates are used to calibrate the PSRC demographic forecasts to current conditions.

WATER DEMAND FORECAST MODEL STRUCTURE



In the first table below is displayed PSRC's forecast of population, households, and employment in King County. The tables that follow contain these forecasts as they have been apportioned into water service areas. Separate tables are provided for all of King County, SPU's retail service area, and the service area of Full and Partial Contracts (F&P) wholesale customers.

Actual[1] & PSRC Forecasts of Population, Households, & Employment

King County

		Households			
	Population	Single Family	Multifamily	Total	Employment
2000	1,737,034	453,437	257,479	710,916	1,196,043
2010	1,892,999	489,880	298,423	788,303	1,144,022
2020	2,075,426	532,658	362,451	895,109	1,498,043
2030	2,234,775	568,799	428,527	997,326	1,664,780
2040	2,401,521	605,712	501,095	1,106,807	1,830,535
2010-2040					
Growth	508,522	115,832	202,672	318,504	686,513
% Change	27%	24%	68%	40%	60%
Annual %	0.8%	0.7%	1.7%	1.1%	1.6%

As Apportioned to SPU's Retail Service Area[2]

		Household			
	Population	Single Family	Multifamily	Total	Employment
2000	618,323	151,741	128,450	280,191	555,410
2010	663,680	157,260	145,645	302,905	506,396
2020	710,784	161,471	175,775	337,246	608,178
2030	753,028	164,415	205,960	370,375	692,684
2040	801,169	167,267	240,078	407,345	781,846
2010-2040					
Growth	137,489	10,007	94,433	104,440	275,450
% Change	21%	6%	65%	34%	54%
Annual %	0.6%	0.2%	1.7%	1.0%	1.5%

As Apportioned to the Full and Partial Contracts Wholesale Service Area

		Household			
	Population	Single Family	Multifamily	Total	Employment
2000	381,658	103,318	40,032	143,351	156,737
2010	410,755	111,054	45,427	156,481	165,834
2020	447,193	121,192	54,608	175,800	187,930
2030	477,889	129,587	64,380	193,967	212,578
2040	511,852	138,012	76,427	214,439	241,712
2010-2040					
Growth	101,097	26,958	31,000	57,958	75,878
% Change	25%	24%	68%	37%	46%
Annual %	0.7%	0.7%	1.7%	1.1%	1.3%

[1] Census data used for 2000 and 2010 population and households. 2010 employment is based on latest (2011) PSRC estimate of 2010 employment.
[2] SPU's retail service area includes the City of Seattle and portions of the cities of Shoreline, Lake Forest Park and Burien, as well as portions of unincorporated King County south of the City of Seattle.

Household size is calculated for single and multifamily households in Seattle and for wholesale customers over the forecast period based on PSRC projections of single and multifamily households and population. Since the number of households is expected to grow faster than population through 2040, household size is projected to decrease over the next 30 years. The estimates of household size are as follows:

	Seattle		SWP Wholesale Customers	
	Single Family	Mutlifamily	Single Family	Mutlifamily
2010	2.41	1.93	2.76	2.25
2020	2.32	1.89	2.59	2.19
2030	2.24	1.85	2.50	2.13
2040	2.16	1.81	2.41	2.08
2050	2.16	1.82	2.40	2.09
2060	2.15	1.82	2.40	2.10

A straight-line extrapolation of average annual growth between 2010 and 2040 is used to forecast population beyond 2040. However, projections of the number of households beyond 2040 are based on the assumption that household size will stabilize and growth in the number of households will slow to about the rate of population growth. Per household flow factors are then reduced each year by the percent change in household size times the elasticity of demand with respect to household size. This elasticity is estimated to be 0.38 based on data from an end-use study conducted by the Seattle Water Department in the mid-1990s.

⇨ **Base Year Flow Factors:** Base year flow factors are obtained by dividing the weather-adjusted base year consumption for each sector (e.g. single family residential) and service area (e.g. Bothell) by the corresponding number of households or employees in the base year.

⇨ **Elasticity of residential demand to changes in real (inflation adjusted) household income:** Household income is generally expected to have a positive effect on water demand. A review of the literature revealed a range of estimated income elasticities. An elasticity value of **0.27**, representing the middle of this range, was chosen. (This means that a 10% increase in household income would be expected to cause a 2.7% rise in residential demand.)

Source: Results of literature review

⇨ **Forecast of annual growth in real median household income:** Mean household income was used in the 2007 WSP but on further reflection, median income appears to be the more appropriate concept. The past 40 years has seen a widening gap between growth in mean and median income. Both national and local time series on real per capita personal income show average annual rates of growth of about 2.0%. However after adjusting for inflation, median household income Washington State and King County is now slightly less than it was in 1989. The growth rate has been essentially zero. There is additional evidence that this is not just true for the median household but for most households except those at the very top of the income distribution. A recent analysis by economists Saez and Piketty based on 90 years of IRS data reveals that *average* household income for the bottom 90% of households has had zero real growth since 1970. Over the same 4 decades, the top 10%, 1%, 0.1%, and 0.01% of households has seen their real incomes increase twofold, threefold, fivefold and eightfold, respectively. If the present trend continues with all income growth going to the top 10%, median income – in fact, the income of the bottom 90% – will remain flat in real terms. More optimistic scenarios would have the increasing skewness in the income distribution slow down, stop, or even reverse. Those conditions would correspond to rates of median income growth greater than zero but less than the average growth rate, equal to the average growth rate, or greater than the average growth rate. For the demand forecast, it is assumed that household income will grow at **0.9%** per year based on the median or about half the historical growth rate in per capita personal income based on averages.

Sources: U.S. Bureau of Economic Analysis, U.S. Census Bureau, Washington State Office of Financial Management, Dick Conway & Associates, Emmanuel Saez of UC-Berkeley.

- **Elasticity of demand to changes in real water rates (prices):** A considerable body of literature has developed concerning the effect of price upon water demand and the inverse relationship predicted by economic theory is now well established. However, a number of complications summarized in the literature review (complex rate structures, conservation impacts, etc.) have made it difficult to estimate price elasticity with much confidence. As a result, there is a wide range of estimates in the literature but as with the income elasticity, values towards the middle of the range have been chosen for this model. These are shown below. (The value of -0.20 for single family households means that given a 10% increase in water prices, demand would be expected to decline by 2%.)

	Single Family	Multifamily	Non-Residential
Price Elasticity	-0.20	-0.10	-0.225

Sources: Results of literature review, Seattle's 1992 econometric model.

- **Forecast of annual growth in real water rates (prices)**: Seattle and its wholesale customers have different water rates and different rate structures. Most customers face different marginal rates depending on whether they're residential or non-residential, what consumption block they fall in and what season it is. There is no single price of water. However, the model abstracts from all these complexities by using the average price of water, i.e., revenue requirements divided by billed consumption.

  The model takes into account the significant increases in water and sewer[3] rates already adopted or anticipated through 2014. After that point, the SPU 20-year rate model forecasts that growth in inflation-adjusted retail water rates will slow to less than half a percent per year on average. The rates charged to SPU's wholesale customers are expected to increase even more slowly. However, wholesale customers have their own system costs to recover from their retail customers and these are likely to increase on a per ccf basis as well. The demand forecast model assumes the following growth rates:

[3] Because sewer bills in Seattle are based on metered water consumption, both water and sewer rates are assumed to impact water demand in the model. This is only the case for the retail service area, however. Many different cities and sewer districts provide sewer service in Seattle's wholesale water service area, each with different sewer rates and rate structures. Unlike Seattle's sewer rates that are entirely volume based, most other sewer providers have large fixed charges with much less of their revenue generated by volume rates. For that reason, as well as lack of information on past, current and anticipated sewer rates in the wholesale service area, the demand model for wholesale customers does not include sewer rates.

Annual Growth in Average Water Rates

	Seattle Retail*	Wholesale Customers
2010-2015	5.1%	2.0%
2016-2060	0.4%	0.4%
2030-2060	0.4%	0.4%

* Reflects anticipated increases in water and sewer rates

These are less than the average historical rate of growth of about 2.7% since 1974 but are consistent with the financial forecast used elsewhere in this Plan.

Sources: Historical rate and consumption data, SPU 20-year rate models for water and wastewater, King County Financial Plan dated June 27, 2011.

⇨ **Conservation - Reductions in Water Use due to Passive Savings:** Some conservation savings occur each year without SPU intervention due to federal and state plumbing codes setting efficiency standards for showerheads, toilets, aerators, and clothes washers. As old fixtures and appliances are replaced with new ones in existing buildings and new fixtures and appliances are installed in new construction, water use efficiency improves and conservation savings accrue. In addition, fixtures and appliances available from the market at competitive prices often become increasingly more efficient than is required by codes, especially as more years have passed since the codes were updated. "Passive savings" is made up of this phenomenon – referred to as "market transformation" – together with "code savings." A new model was developed to estimate these savings through 2060.

The model takes account of federal fixture and appliance codes adopted in 1992, 2002 and 2007. In addition, the impact of new clothes washer standards adopted in 2012[4] is included. The model also reflects the current proportion of fixtures and appliances sold in the market that meet the more stringent Energy Star, Water Sense, and Consortium for Energy Efficiency (CEE) standards, as well as how those proportions are expected to continue shifting in the direction of higher efficiency over time. The model assumes that aerators, showerheads, clothes washers and toilets are, on average, replaced every 5, 10, 12 and 30 years, respectively.

Passive Savings in MGD

	Single Family	Multi-family	Non-Residential	Total
2020	2.5	1.7	0.6	4.9
2030	5.6	4.0	1.2	10.8
2040	7.5	5.8	1.7	15.0
2050	8.5	7.0	2.1	17.7
2060	9.0	7.8	2.4	19.2

Sources: Conservation Potential Assessment (CPA) model, U.S. EPA Office of Water, Alliance for Water Efficiency, Al Dietemann (personal communication)

[4] The US Department of Energy has adopted a two phase residential clothes washer efficiency standard, with the first phase effective March 7, 2015, and the second, more stringent phase, effective for January 1, 2018. A new commercial clothes washer efficiency standard adopted in 2012 went into effect on January 8, 2013.

⇨ **Conservation - Reductions in Water Use due to Programmatic Savings:** Based on the January 2006 decision by the Seattle Regional Water System Operating Board, the forecast includes **15** mgd of combined price-induced and programmatic conservation savings between 2011 and 2030, by assuming that demand is reduced evenly by 0.75 mgd each year over the 20-year period. Depending on what is assumed about the growth rate in water and sewer prices, more or less programmatic savings are required to meet this target. The price assumptions described above are estimated to produce a 7 mgd reduction in demand by 2030 leaving **8 mgd** to be achieved through programmatic conservation, assuming no price/conservation overlap (described below). This is equivalent to 0.4 mgd per year. These conservation savings only apply to Seattle and other members of the Saving Water Partnership. As is explained below, the Cascade Water Alliance has a block contract with SPU which limits its demand from the Seattle system. While Cascade is expected to pursue its own conservation programs, that doesn't affect the forecast of its demand from SPU which is assumed not to exceed the block. There is assumed to be no additional programmatic conservation after 2030.

⇨ **Price/Passive/Programmatic Conservation Overlap:** Total conservation savings is adjusted downwards to account for the overlap between the different types of conservation. It is assumed that half of the price effect overlaps with passive and programmatic savings as long as the total amount of overlap represents less than half of total passive and programmatic conservation (as is the case over the forecast period). However, if the price effect exceeds combined passive and programmatic conservation, the amount of overlap is capped at 50%. The overall effect of the overlap function is to reduce total gross price/passive/programmatic savings by about 14%. For accounting purposes, the amount of overlap is deducted from the estimate of passive savings.

⇨ **Non-Revenue Water:** Combined transmission and Seattle distribution system non-revenue water is assumed to start at **8** mgd in 2010 and increase uniformly to **10** mgd by 2060. This increase is expected to be caused by a growing number of leaks that will probably occur as the distribution system ages.

⇨ **Wholesale Customer Demands:**

- Wholesale customer distribution system non-revenue water is assumed to be a constant **6%** of retail water demand in the wholesale service area over the forecast period. This is added to the forecast of wholesale customers' retail demand.

  Source: Annual Surveys of Wholesale Customers, 1994-2010.

- Water that full and partial contract wholesale customers expect to obtain from other sources of supply is subtracted from their demand from the SPU system. This amount is currently about **16** mgd and is projected to reach **18.5** mgd by 2020.

  Sources: 2010 Survey of Wholesale Customers, direct communication with individual wholesale customers.

- Contract with the Cascade Water Alliance (Cascade). Under the Cascade contract as amended July 2013, Seattle will provide a fixed block of **33.3** mgd to Cascade through 2039. The block will then be reduced by **2** mgd per year for the three years beginning in 2040, and **1** mgd per year thereafter until it reaches **5.3** mgd in 2064. This has been incorporated into the forecast by subtracting the projected demand of Cascade members that are currently Seattle wholesale customers, and adding the Cascade block.

The following cities and districts are members of Cascade[5]:

- Bellevue
- Kirkland
- Issaquah
- Redmond
- Sammamish Plateau
- Skyway
- Tukwila

- Block contract with Northshore Utility District. Northshore Utility District also has a block contract under which Seattle will reserve a fixed block of **8.6** mgd for Northshore through the contract period which terminates in 2060. This has been incorporated into the forecast by subtracting Northshore's projected demand and adding the Northshore block. Note that current Northshore demand is about 3 mgd less than its block. By 2060, actual Northshore demand is expected to have grown to 7.3 mgd, still less than its block by more than 1 mgd.

- Forecasts of demand from potential new wholesale customers are based on data provided by them on their projected demand and existing supplies. Potential new wholesale customers included in the forecast are Ames Lake Water Association and City of Carnation. Demand from Ames Lake is expected to begin at zero ramping up to **0.5** mgd by 2033 and remaining constant thereafter. Carnation purchases from SPU are also expected to start at zero, ramp up to **0.5** mgd by 2028, and then remain constant. The City of Snoqualmie is also considered a potential new wholesale customer, but no specific demand is included in this forecast.

  Sources: Ames Lake Water Association, City of Carnation, City of Snoqualmie.

- Historically, Renton's water purchases from SPU have been negligible, but that is expected to change over time under the new contract as its demand begins to exceed its peak day capacity. Renton has provided a forecast of its estimated requirements from SPU ramping up to **0.9** mgd by 2060.

- Highline reduces demand from SPU by **2** mgd in 2016 by purchasing water from Lakehaven and completing a new well.

- Edmonds and Lake Forest Park are no longer included as wholesale customers. They do not purchase water from SPU nor do they have supply contracts after 2011 for regular supply.

Results

Given the assumptions described above, the water demand forecast is higher than the last official forecast, but remains considerably below SPU's current firm yield of 172 mgd through at least 2060. The demand forecast starts out at **133** mgd, higher than actual demand in 2010 because the forecast includes the Cascade and Northshore blocks that currently exceed the actual demand of those customers by 12 mgd. Total demand is forecast to gradually increase to **142 mgd by 2039** and then decline with the initial reductions in Cascade's block. Water demand is forecast to **stay relatively flat at about 137 mgd through 2060** as reductions in Cascade's block offset what would otherwise be a modest amount of growth in demand.

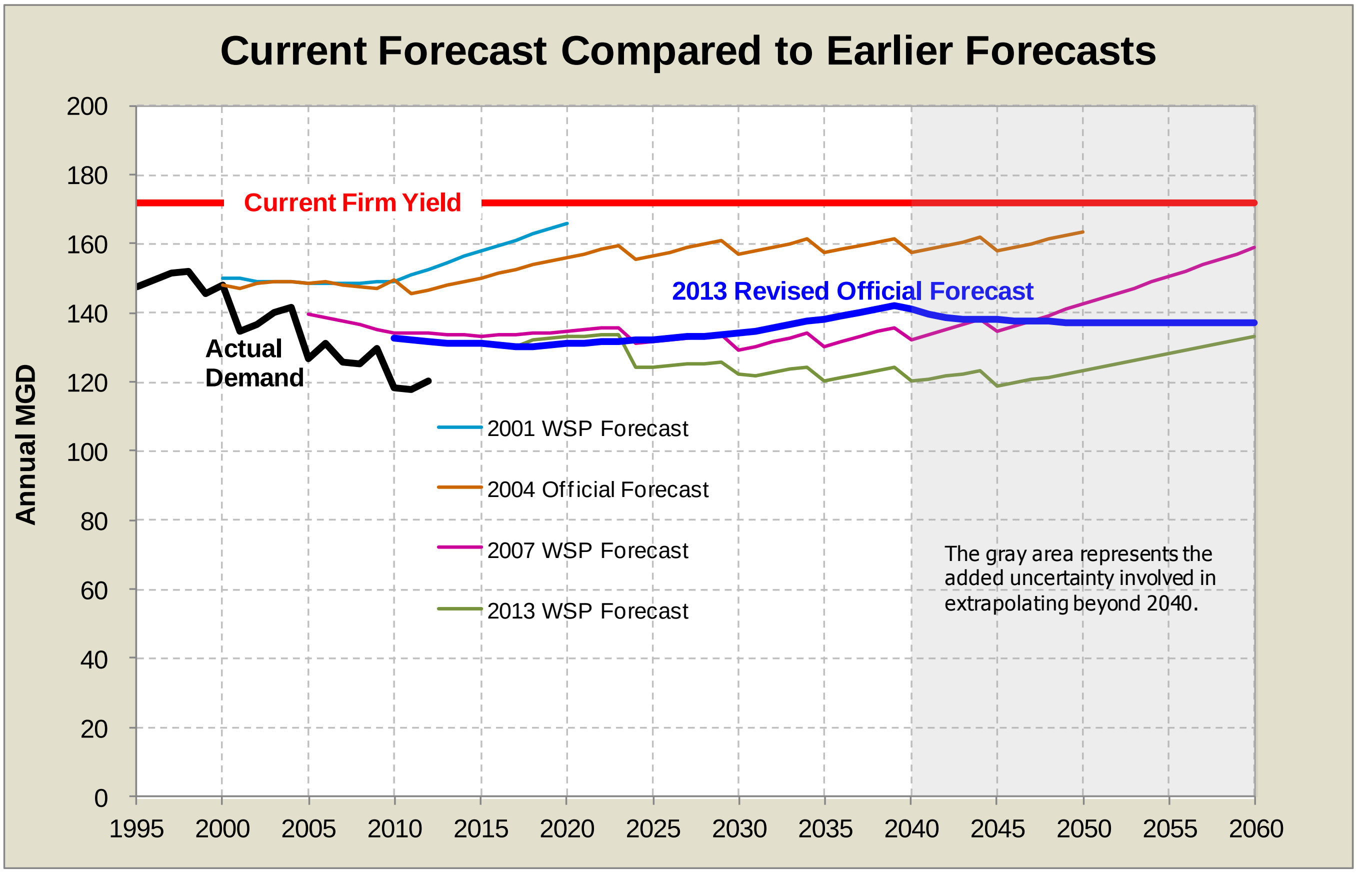
The 2013 Revised Official Forecast broken down by sector is shown in the table and graphs below. The first graph shows the forecast of demand and supply out to 2060 along with previous WSP forecasts. The gray area between 2040 and 2060 represents the additional uncertainty involved in forecasting out more than 30 years The second graph shows the various components that add up to the total demand forecast: Seattle retail, full and partial contract wholesale customers, the amounts specified in the Northshore and Cascade block contracts, potential new wholesale customers, and non-revenue water.

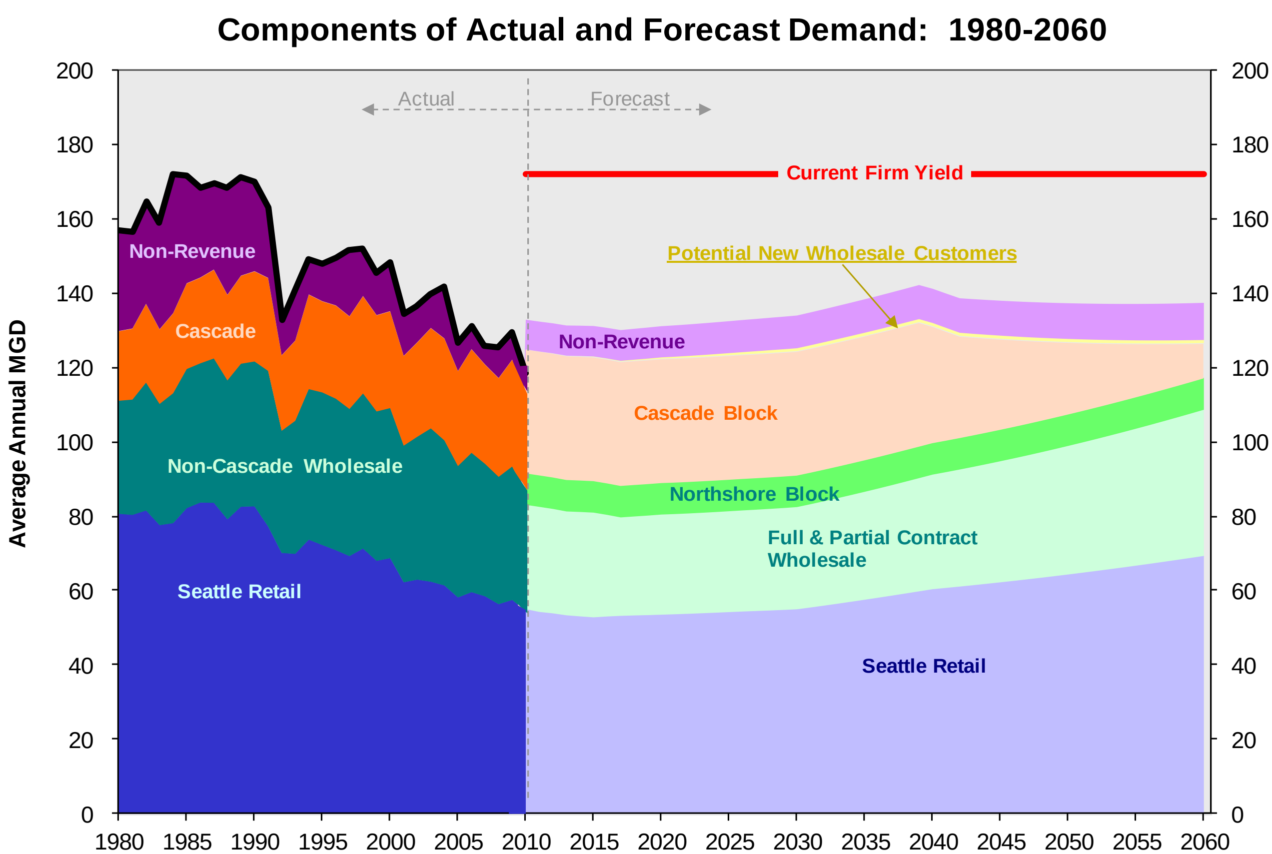
[5] Covington Water District left Cascade Water Alliance in 2012.

Components of Actual and Forecast Water Demand
All figures in millions of gallons per day (MGD)

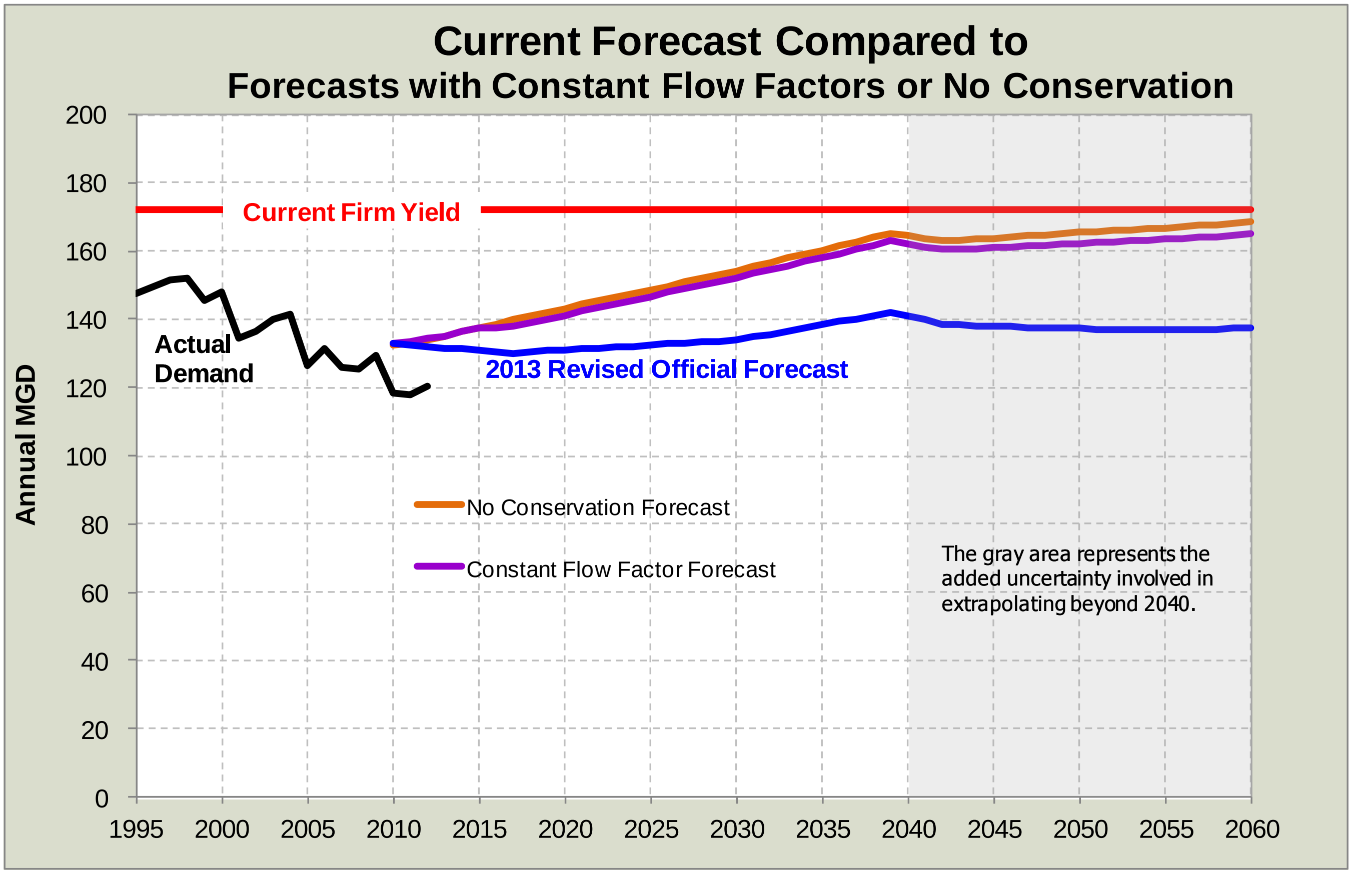
	Year	Billed Demand								Non-Revenue Water	Total System Demand	
		Seattle Retail				Wholesale					Annual Average[4]	Peak Day[5]
		SF Res	MF Res	Non-Res	Subtotal	F&P[1]	Block[2]	New[3]	Subtotal			
	2000	26.9	14.5	27.7	69.1	34.3	31.7	-	66.0	13.2	148.2	241.9
	2001	24.0	13.7	24.6	62.3	30.0	30.8	-	60.7	11.6	134.6	204.0
A	2002	24.8	13.1	24.9	62.8	32.9	31.0	-	63.9	9.8	136.5	222.6
C	2003	24.9	12.8	24.6	62.3	35.6	32.7	-	68.2	9.4	139.9	250.2
T	2004	24.2	12.5	24.6	61.3	33.1	33.3	-	66.4	14.0	141.7	246.8
U	2005	22.6	12.2	23.2	58.0	29.6	31.4	-	61.0	7.7	126.7	210.4
A	2006	23.5	12.3	23.7	59.5	32.0	33.4	-	65.4	6.3	131.2	236.8
L	2007	22.6	12.0	23.6	58.3	28.7	33.7	-	62.5	5.2	125.9	227.6
	2008	22.0	11.8	22.5	56.3	28.8	32.0	-	60.8	8.2	125.3	202.0
	2009	23.1	11.6	22.6	57.3	30.6	34.1	-	64.8	7.5	129.5	241.9
	2010	21.3	11.4	21.6	54.3	26.5	29.6	-	56.1	8.0	118.4	197.9
	2010	21.9	11.4	21.6	55.0	28.0	41.9	0.0	69.9	8.0	132.8	265.7
	2011	21.5	11.5	21.2	54.2	28.2	41.9	0.0	70.1	8.0	132.3	264.7
	2012	21.2	11.6	21.0	53.8	28.1	41.9	0.1	70.0	8.1	131.9	263.8
F	2013	20.9	11.6	20.8	53.3	27.9	41.9	0.1	69.9	8.1	131.3	262.6
O	2014	20.7	11.7	20.7	53.0	28.1	41.9	0.2	70.1	8.2	131.2	262.5
R	2015	20.4	11.7	20.6	52.8	28.1	41.9	0.2	70.2	8.2	131.2	262.3
E	2016	20.3	11.8	20.9	53.0	27.3	41.9	0.3	69.4	8.2	130.6	261.3
C	2017	20.2	11.8	21.1	53.2	26.5	41.9	0.3	68.6	8.3	130.1	260.1
A	2018	20.1	11.9	21.3	53.3	26.6	41.9	0.4	68.8	8.3	130.4	260.8
S	2019	19.9	12.0	21.5	53.4	26.8	41.9	0.4	69.0	8.4	130.7	261.5
T	2020	19.7	12.0	21.7	53.5	26.9	41.9	0.5	69.2	8.4	131.1	262.2
	2021	19.5	12.1	22.0	53.6	26.9	41.9	0.5	69.3	8.4	131.3	262.7
	2022	19.3	12.1	22.3	53.7	27.0	41.9	0.6	69.4	8.5	131.6	263.2
	2023	19.1	12.1	22.6	53.9	27.0	41.9	0.6	69.5	8.5	131.9	263.7
	2024	18.9	12.2	22.9	54.0	27.1	41.9	0.7	69.6	8.6	132.1	264.3
	2025	18.7	12.2	23.2	54.2	27.1	41.9	0.7	69.7	8.6	132.5	264.9
	2026	18.5	12.3	23.5	54.3	27.2	41.9	0.8	69.8	8.6	132.8	265.5
	2027	18.3	12.3	23.8	54.5	27.2	41.9	0.8	69.9	8.7	133.1	266.1
	2028	18.1	12.4	24.1	54.6	27.3	41.9	0.9	70.0	8.7	133.4	266.7
	2029	18.0	12.5	24.3	54.8	27.4	41.9	0.9	70.1	8.8	133.7	267.3
	2030	17.8	12.5	24.6	54.9	27.5	41.9	0.9	70.3	8.8	134.1	268.1
	2031	17.7	12.7	25.0	55.4	27.8	41.9	1.0	70.6	8.8	134.8	269.6
	2032	17.7	12.9	25.4	55.9	28.1	41.9	1.0	70.9	8.9	135.7	271.4
	2033	17.6	13.0	25.8	56.4	28.4	41.9	1.0	71.2	8.9	136.6	273.1
	2034	17.6	13.2	26.1	57.0	28.7	41.9	1.0	71.5	9.0	137.4	274.9
	2035	17.6	13.4	26.5	57.5	29.0	41.9	1.0	71.9	9.0	138.3	276.7
	2036	17.5	13.6	26.9	58.0	29.3	41.9	1.0	72.2	9.0	139.3	278.5
	2037	17.5	13.8	27.3	58.6	29.7	41.9	1.0	72.5	9.1	140.2	280.4
	2038	17.5	13.9	27.7	59.2	30.1	41.9	1.0	72.9	9.1	141.2	282.4
	2039	17.5	14.1	28.1	59.7	30.4	41.9	1.0	73.3	9.2	142.2	284.3
	2040	17.5	14.3	28.5	60.3	30.8	39.9	1.0	71.6	9.2	141.2	282.3
5	2045	17.6	15.2	29.4	62.2	32.5	32.9	1.0	66.4	9.4	138.0	275.9
	2050	17.8	16.1	30.4	64.3	34.6	27.9	1.0	63.4	9.6	137.3	274.5
Y	2055	18.0	17.3	31.4	66.6	36.8	22.9	1.0	60.7	9.8	137.1	274.2
R	2060	18.2	18.6	32.4	69.2	39.3	17.9	1.0	58.1	10.0	137.4	274.8

1. F&P refers to Full and Partial contracts wholesale customers.
2. The forecast of demand from Cascade Water Alliance (Cascade) and Northshore is equal to their blocks while the historical consumption data reflects water actually purchased from SPU by Cascade members and Northshore. The blocks exceeded actual water purchases from SPU of Cascade members and Northshore by 12 mgd in 2010.
3. Potential new wholesale customers
4. The forecast of Total System Demand includes the Northshore and Cascade blocks while the historical consumption data reflects SPU water actually purchased by Northshore and Cascade.
5. The forecast of peak day demand is based on a peak day factor of 2.0, the ratio of peak day to average annual demand in 2009 with a 5% allowance for hot, dry weather. The forecast of average annual demand under average weather conditions is multiplied by the peak day factor to estimate peak day demand with hot, dry weather.

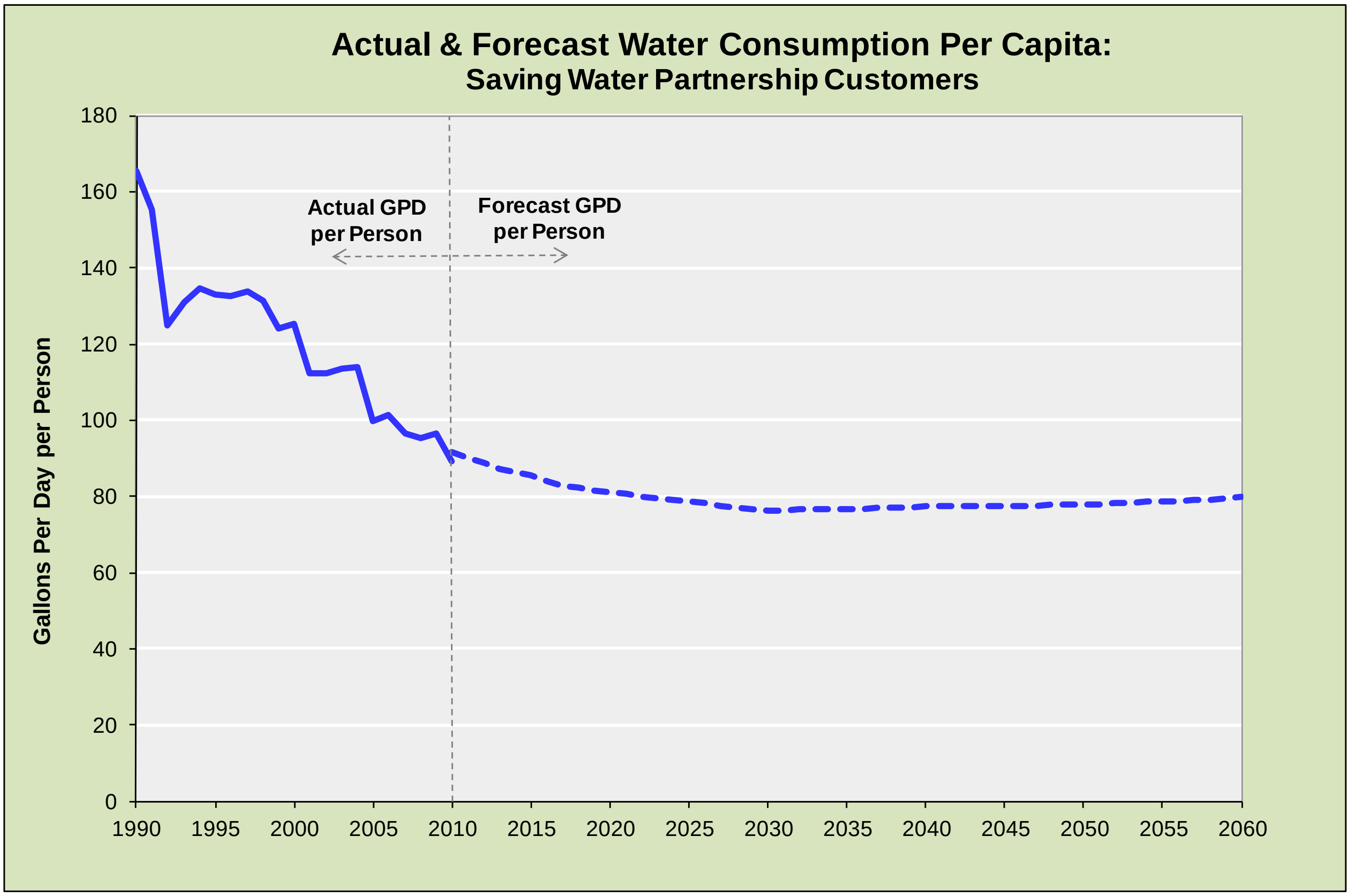

Current Forecast Compared to Earlier Forecasts
Annual MGD
200
180
160
140
120
100
80
60
40
20
0
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
Current Firm Yield
2013 Revised Official Forecast
Actual Demand
2001 WSP Forecast
2004 Official Forecast
2007 WSP Forecast
2013 WSP Forecast
The gray area represents the added uncertainty involved in extrapolating beyond 2040.


Components of Actual and Forecast Demand: 1980-2060
Average Annual MGD
200
180
160
140
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
Actual
Forecast
Current Firm Yield
Potential New Wholesale Customers
Non-Revenue
Cascade
Non-Cascade Wholesale
Seattle Retail
Non-Revenue
Cascade Block
Northshore Block
Full & Partial Contract Wholesale
Seattle Retail

The graph below contrasts the official demand forecast with what it would be with constant flow factors and with no future conservation of any kind (i.e., no price effect, no passive savings, and no programmatic savings). Note that the forecast with "no conservation" is slightly higher than the forecast holding water flow factors constant over time because the "no conservation forecast" includes the impact of income growth and changes in household size, which net to a small increase in flow factors. For the revised 2013 forecast, all sources of conservation are estimated to produce a total reduction in water demand of more than 30 mgd by 2060.



Finally, the implications of the new demand forecast for total system per capita water consumption are shown in the graph below. Due to anticipated programmatic conservation, passive savings, and water and sewer rate increases, per capita consumption is forecast to continue declining over the next 20 years though at a slower rate than in the past. By 2030, per capita consumption is expected to level off at about 80 gallons per day (gpd) (compared to 90 gpd currently). In contrast, between 1990 and 2010, total and per capita water consumption for Seattle and its non-Cascade wholesale customers declined 46% from 166 gallons per day (gpd) to 89 gpd. The demand model does not imply ever-decreasing per capita consumption.



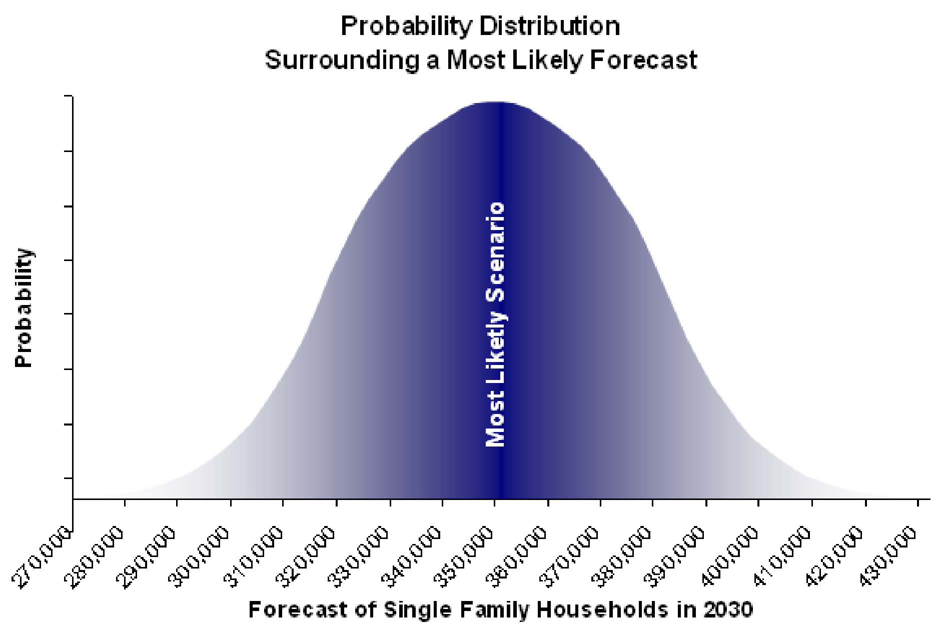
Forecast Uncertainty

What is most certain about a forecast out to 2060 is that it will be wrong. Actual demand in 2040 or 2060 is highly unlikely to be exactly what was forecast back in 2013. The official water demand forecast is itself based on forecasts of income, water prices, households and employment – all subject to uncertainty. Additional uncertainty surrounds the forecast model's assumptions about price and income elasticities, future conservation, wholesale customers' other sources of supply, and whether SPU will gain new customers and/or lose existing customers.

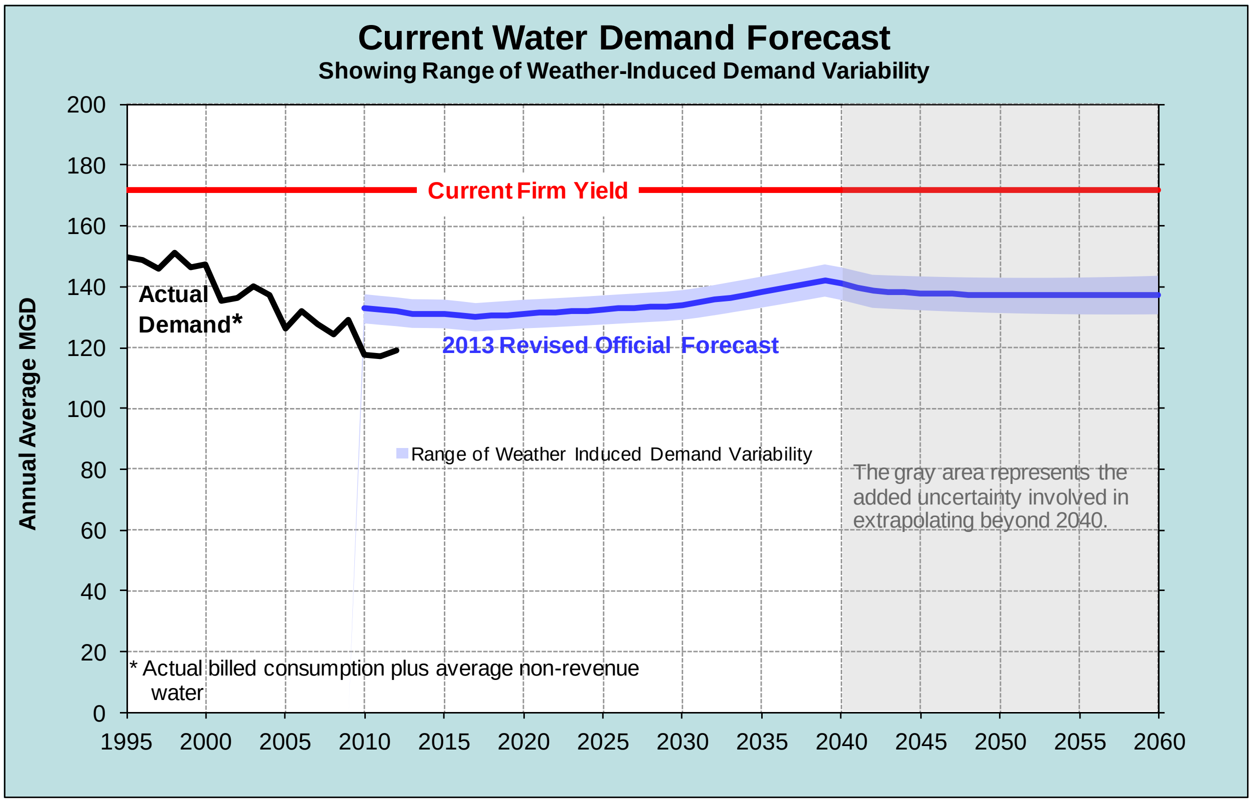
The Official Demand Forecast represents both SPU's policy intentions and its expectations of the future. However, it is prudent, especially in long-term planning, to consider the many uncertainties that could cause demand to be different from what's projected in the official forecast. These uncertainties fall into two categories – discrete and continuous – and are handled in two different ways.

The first category refers to those uncertainties that result from discrete events that produce significant and sometimes abrupt changes in customer demand. Discrete uncertainties represent occurrences that either happen or don't. They're on or off, yes or no (though there can be more than two conditions). An example of a discrete uncertainty is the block contract with Cascade Water Alliance. This and other discrete uncertainties are thought to be best handled by running individual "what-if scenarios" through the demand forecast model.

The second category consists of the continuous uncertainty that surrounds the various inputs to the model. An example would be the forecast of household growth. Actual growth over the forecast period could turn out to be lower or higher than forecast. These types of uncertainties can be represented by a continuous probability distribution around a mean or most likely value as illustrated below.



Weather-Induced Demand Variability: Another source of "fuzziness" in the forecast is weather-induced demand variability. However, this is not really a matter of uncertainty because there is no doubt that summer weather will continue to vary from year to year, and that this variation will cause water demand to fluctuate around the trend. Because base year flow factors are calculated from weather-adjusted consumption data, the forecast represents demand under average weather conditions. Analysis of daily consumption data back to 1982 shows a maximum variability of about plus or minus **5%**. In other words, an extremely hot dry summer would be expected to increase annual consumption *in that year* by up to 5% above the average trend. An extremely cold wet summer would be expected to do the opposite, reducing that year's annual consumption by about 5% below the average trend. The amount by which actual demand is expected to be higher or lower than forecast due to variation in summer weather is shown as the blue band around the forecast in the graph below.



This does not explicitly account for the potential impact of climate change on future demand. While higher summer temperatures are anticipated over the next century due to climate change, most climate model/emission scenario combinations do not project average temperatures to rise above what has already been experienced in hot years. Therefore, the impact of climate change on future demand is not expected to increase the average-weather forecast beyond the range of weather-induced demand variability. SPU's analysis of the impact of climate change on future demand and supply is summarized in the main text of the *2013 Water System Plan*.

Modeling Continuous Uncertainty

A number of model inputs were identified as being subject to continuous uncertainty. (These are shown in the model structure flowchart on page 2 shaded in gray.) They include forecasts of single and multi-family households and employment; average annual growth rates for water prices and household income; price and income elasticities; the impact of passive savings; and the extent to which price-induced conservation overlaps with passive and programmatic conservation. Each uncertainty was modeled by specifying a probability distribution around the mean value of each variable. Many sources were consulted to define the range of uncertainty[6] and the shape of the distributions. The sources and assumptions used to characterize continuous uncertainties are outlined below.

Forecasts of Households and Employment: Two different sources were consulted to establish uncertainty ranges around the forecasts of long term demographic growth. In 2007, the Washington State Office of Financial Management (OFM) produced high and low forecasts of population by county based on historical variability in net migration rates. Dick Conway and Associates developed high and low alternatives around the 2002 PSRC long term regional forecasts of population and employment (but not households) based on optimistic and pessimistic scenarios for the local and national economies[7]. The greater geographical specificity of the OFM forecasts was combined with the more rigorous methodology and wider range between low and high provided by Dick Conway's analysis. The OFM uncertainty ranges are calibrated to 2005 and the Conway uncertainty ranges are calibrated to 2000. Both were brought forward and calibrated to 2010 so that low, medium and high forecasts all start of from the same point in 2010. The ranges of uncertainty around the projections of households, employment and population used in the demand forecast model are shown in the table, below. The forecast number of multifamily households in 2060, for example, is 28% less than the baseline forecast in the low growth scenario and 47% higher in the high growth scenario.

Uncertainty Ranges Around Mean Values
Associated with High and Low Demographic Growth Scenarios

	2030		2060	
	Low	High	Low	High
Single Family Households	-6%	9%	-10%	18%
Multifamily Households	-16%	26%	-28%	47%
Employment	-7%	12%	-14%	24%
Population*	-11%	17%	-21%	35%

* The number of single and multifamily households rather than population is used in the demand forecast model.

The ranges around single and multi-family households were derived from the reported high and low population values and the assumption that variability around the single family forecast is less than for the forecast of multifamily households. Note that the potential variation from forecast values is expected to be greater on the high side than on the low side.

Growth in the Price of Water: System water rates are obtained by dividing each year's projected revenue requirement by projected demand. Uncertainty about future water prices derives from variability in both of these terms. The baseline assumption is that after significant increases in water and sewer rates already adopted or anticipated through 2014, growth in inflation-adjusted retail water rates will ramp down to 0.4% per year by 2020 and remain there through the forecast period. This is slower than the average historical rate of growth but is consistent with the 20-year rate model forecast used elsewhere in this Plan. The range of uncertainty around this is skewed very much on the high side, **minus 50% to**

[6] Each range is characterized by a high and low value representing two standard deviations from the mean.
[7] Scenarios developed by DRI-WEFA (now known as Global Insights, Inc.)

plus 350%, resulting in projected annual growth rates in real prices of between **0.2%** and **1.8%**.

The model handles the impact on price of different levels of projected demand in a different way. Given the same set of revenue requirements, lower demand results in higher water prices and vice versa. That means that price effects would be expected to amplify swings in demand. For example, higher-than-projected demographic growth would cause demand to be higher than the official forecast, resulting in reduced prices and an additional boost in demand. The amount of the boost is determined by the price elasticity of demand and the amount by which prices fall. Incorporating this demand-price-demand-etc. feedback loop explicitly into the model isn't feasible because, as is explained in more detail below, the uncertainty analysis involves running 10,000 iterations of the demand model. However, the feedback loop has been approximated by widening the range of uncertainty around growth in households and employment. The amounts by which the ranges have been increased are **5.2%** on the high side and **5.3%** on the low side[8].

Price Elasticity: The uncertainty ranges around price elasticity represent a synthesis of the various estimates of price elasticity reported in the literature review. These are **plus or minus 50%** for single and multi-family elasticities and **plus or minus 33%** around the non-residential elasticity.

Uncertainty Ranges Around Mean Price Elasticities

	Single Family	Multi-Family	Non-Residential
Low	-0.10	-0.05	-0.15
Mean	-0.20	-0.10	-0.225
High	-0.30	-0.15	-0.30

Growth in Real Household Income: There is some uncertainty about future growth in average income but much more uncertainty around the distribution of that growth. As explained above, there has been a decoupling of average and median income growth over the past 4 decades. While overall per capita income has averaged 1.8% annual growth since 1970, median income and in fact, the income of the bottom 90% of households has grown very little if at all in real terms. Practically all the growth in national income has gone to households at the very top of the income scale in the last 40 years - the top 10%, 1%, 0.1%, and 0.01% of households seeing their real incomes rise twofold, threefold, fivefold and eightfold, respectively. The baseline assumption in the demand forecast is that median income will grow at **0.9%** annually, about half the rate expected for average income. This scenario represents a slowing of the rate at which the distribution of income gets worse. The continuation of present trends with all income growth going to the top 10% and **zero** income growth for median households is the most pessimistic scenario in the uncertainty analysis. At the high end is the assumption that income grows proportionally across all households and the increasing skewness in the income distribution comes to a halt. Here, annual growth in average income equals that for median income equals **1.8%.**

Income Elasticity: As with price elasticity, the uncertainty band around income elasticity was derived from the various estimates of income elasticity in the literature review. A range

[8] These percents were obtained by calculating the percent changes in 2060 water prices that would result from the high and low growth scenarios relative to the baseline scenario and multiplying them by the average price elasticity.

of income elasticities from **0.19** to **0.35** (i.e., **plus or minus 30%**) around the mean value of 0.27 was chosen.

Passive Savings: Passive savings could be more or less than modeled. If the new clothes washer codes scheduled to go into effect in 2015 are reversed and market transformation towards fixtures and appliances that exceed code occurs slower than anticipated, passive savings could be less than estimated for the baseline forecast. Alternatively, if additional codes are passed in the future, market transformation takes place more quickly, and green buildings become the norm for new construction, passive savings could be more than estimated for the baseline forecast. A range of passive savings from **11.5** to **26.9 mgd** (i.e., **plus or minus 40%**) around the mean value of 19.2 mgd was chosen.

Conservation Savings: The price/code/programmatic conservation overlap function is used to introduce an element of uncertainty to overall conservation savings. The baseline assumption is that 50% of the price effect overlaps with code and programmatic conservation. Assuming a higher level of overlap produces a smaller amount of total conservation savings, and vice versa. A range of conservation savings are obtained in the model by varying the overlap parameters between **25%** and **75%**.

Modeling Uncertainty with @Risk: The uncertainty ranges described above are assumed to have normal or log-normal distributions,[9] with the endpoint values representing two standard deviations from the mean. These probability distributions become inputs to an aggregate uncertainty model using @Risk software (an add-in to Excel) which employs Monte Carlo simulation to characterize uncertainty around the official demand forecast. During each individual run of the Monte Carlo simulation, a value is randomly selected for each input variable based on the probability density function specified for that variable[10]. Then, the complete set of input values for that iteration is used to produce a water demand forecast. The simulation procedure performs a large number (10,000) of independent iterations, each generating a separate demand forecast. These forecasts are then pooled to obtain a probability distribution of forecast water demand through 2060.

The results of the Monte Carlo simulation are displayed in the graph on the next page. The green bands indicate the range of uncertainty around the official forecast with each band representing a 5% change in probability. For example, the bottom of the lowest band represents the 5th percentile. That means it's estimated there's a 5% chance actual demand will be below that point (and, thus, a 95% chance it will be above). The top band is the 95th percentile which corresponds to an estimated 95% probability that actual demand will be below that point. Taking a cross-section of the graph at 2060 produces the probability distribution around the official forecast shown below.

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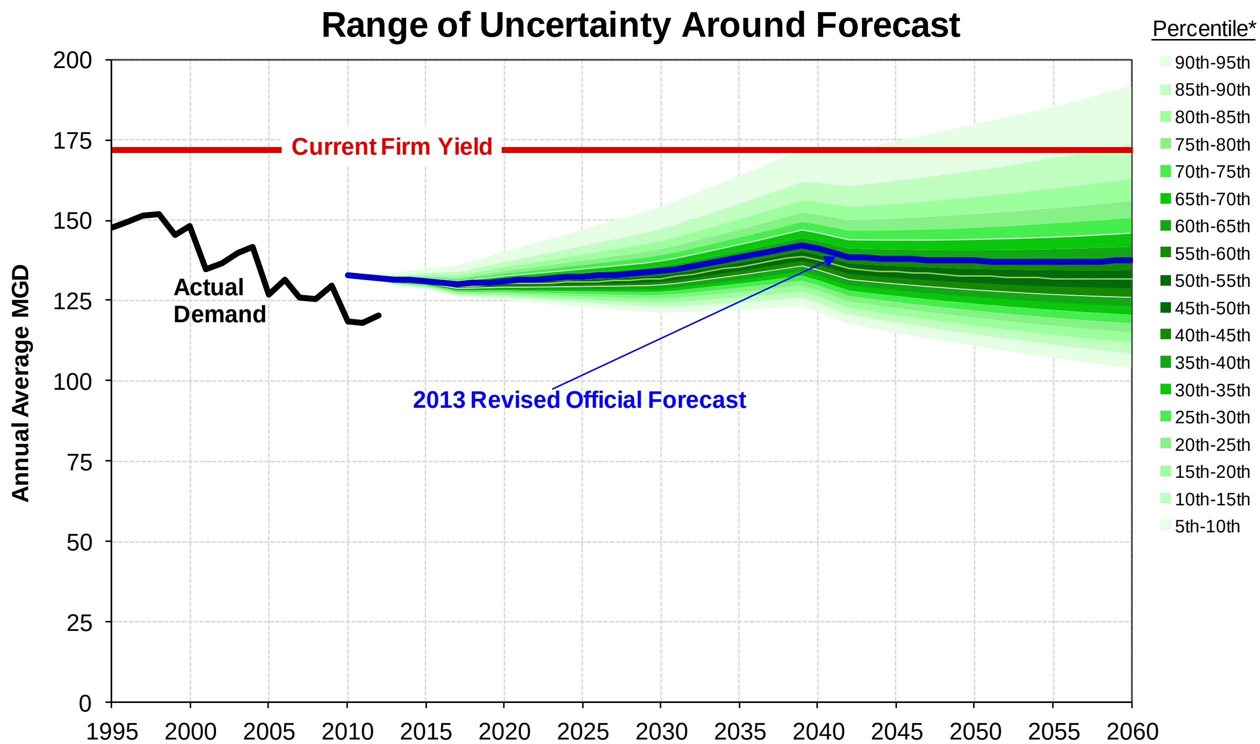
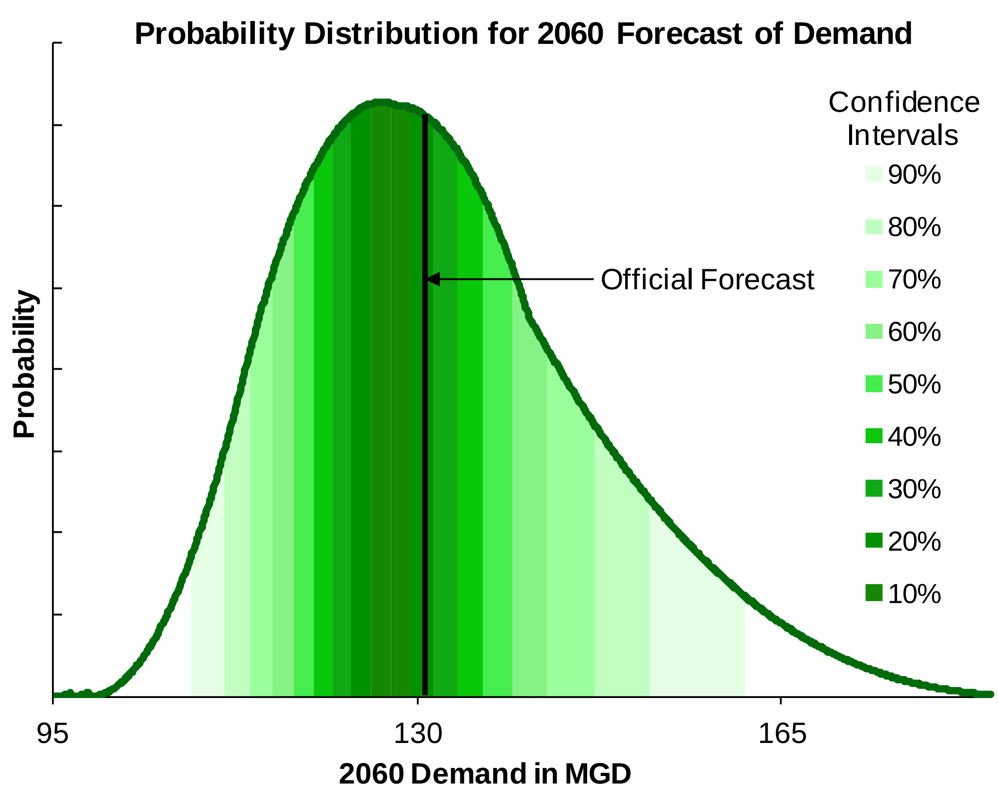
[9] Log normal distributions are used for the uncertainty around household and employment growth and average annual rate of growth in water prices because the high and low ranges exhibit positive skewness (i.e., the highs are higher than the lows are low).

[10] All variables with uncertainty are assumed to be independent except for growth in households and employment. These are linked in the model because they would be expected to move together.



* Percentiles represent the probability that demand is less than the value shown. Ranges reflect uncertainty in projected household, employment, price and income growth; price and income elasticities; and conservation. Note that the Official Forecast is at about the 60th percentile.



The uncertainty model represents a significant refinement over simply compounding all the high or all the low assumptions to create extreme high and extreme low scenarios. In the extreme high scenario, everything that could possibly cause demand to be higher than forecast is assumed to happen at the same time. The extreme low scenario is just the opposite with all low side assumptions applied simultaneously. These extreme scenarios overstate the actual uncertainty surrounding demand because they represent two highly unlikely combinations of events with essentially zero probability of occurring. The Monte Carlo simulation provides narrower bands of uncertainty and information about their estimated probabilities.

Implications: Given the current firm yield estimate for SPU's existing supply resources and the official demand forecast, a new source of supply will not be needed until well after 2060. Taking demand uncertainty into consideration, there's still more than a 90% probability that a new source will not be necessary before 2060. This analysis does not explicitly calculate the possible impact of the "discrete" category of uncertainties mentioned in the introduction. However, none of the discrete uncertainties that have been identified (e.g. changes in the Cascade contract) would shift the forecast of demand beyond the range calculated for continuous uncertainties and shown in the graph, above.